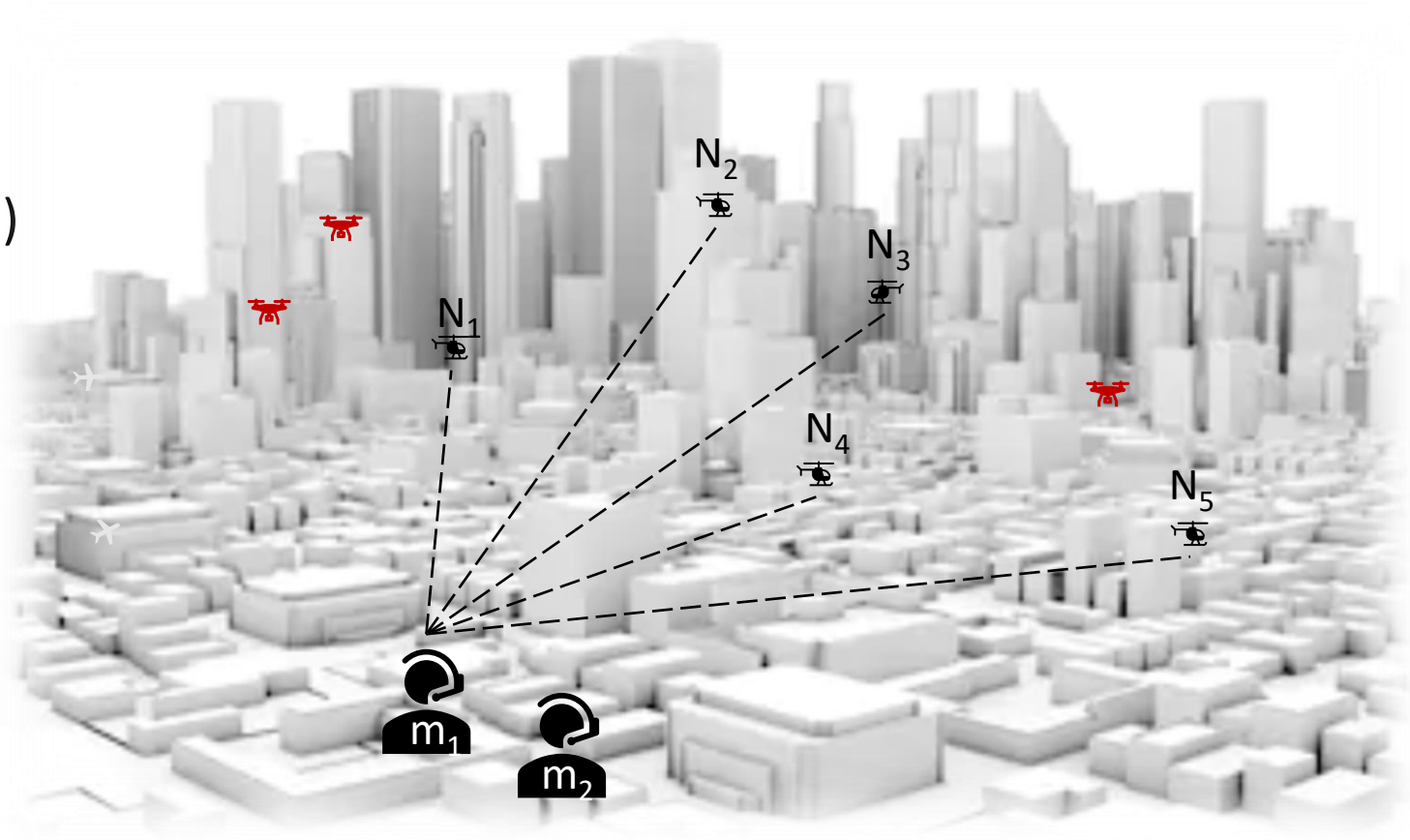
# Transformational Tools & Technologies ($T^3$) Project
# m:N Operations of Autonomous Fleets

Kelley Hashemi, Autonomous Systems Technical Lead

# m:N operations

## Multi-vehicle control = m:N

- Small group of humans (m) *manages* many highly automated air vehicles (N)
- Not flight vehicle control




## Enables desired future state

- Operations scalability
- Cost savings
- Long-term safety benefits

**Applicable to range of use cases supporting of advanced air mobility vision**

# TTT leads m:N across ARMD

## Advanced Air Mobility (AAM)

- m:N ConOps development for high density vertiport operations
- Human factors analysis of simulated and live BVLOS operation
- Multi-vehicle ground control station development

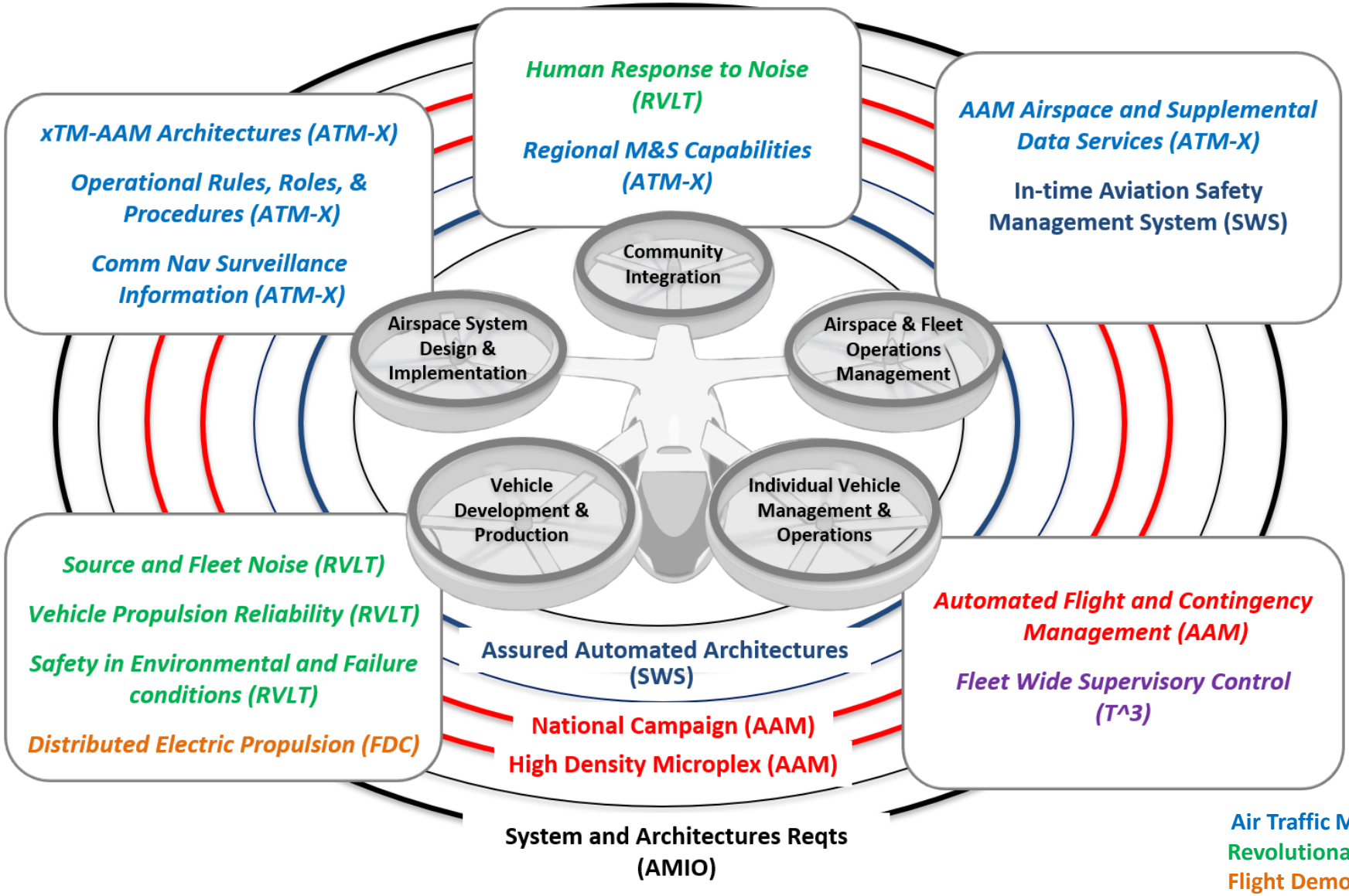

## System-Wide Safety (SWS)

- Vehicle autonomy benchmark development
- m:N ConOps development
- Technical challenge includes human-autonomy teaming for multi-vehicle wildfire response

## Air Traffic Management—Exploration (ATM-X)

- Coordination of m:N plans with far-term CONOPS
- Auto cargo use case participation
- ATC communication architecture coordination

# m:N across ARMD




**Project Legend**

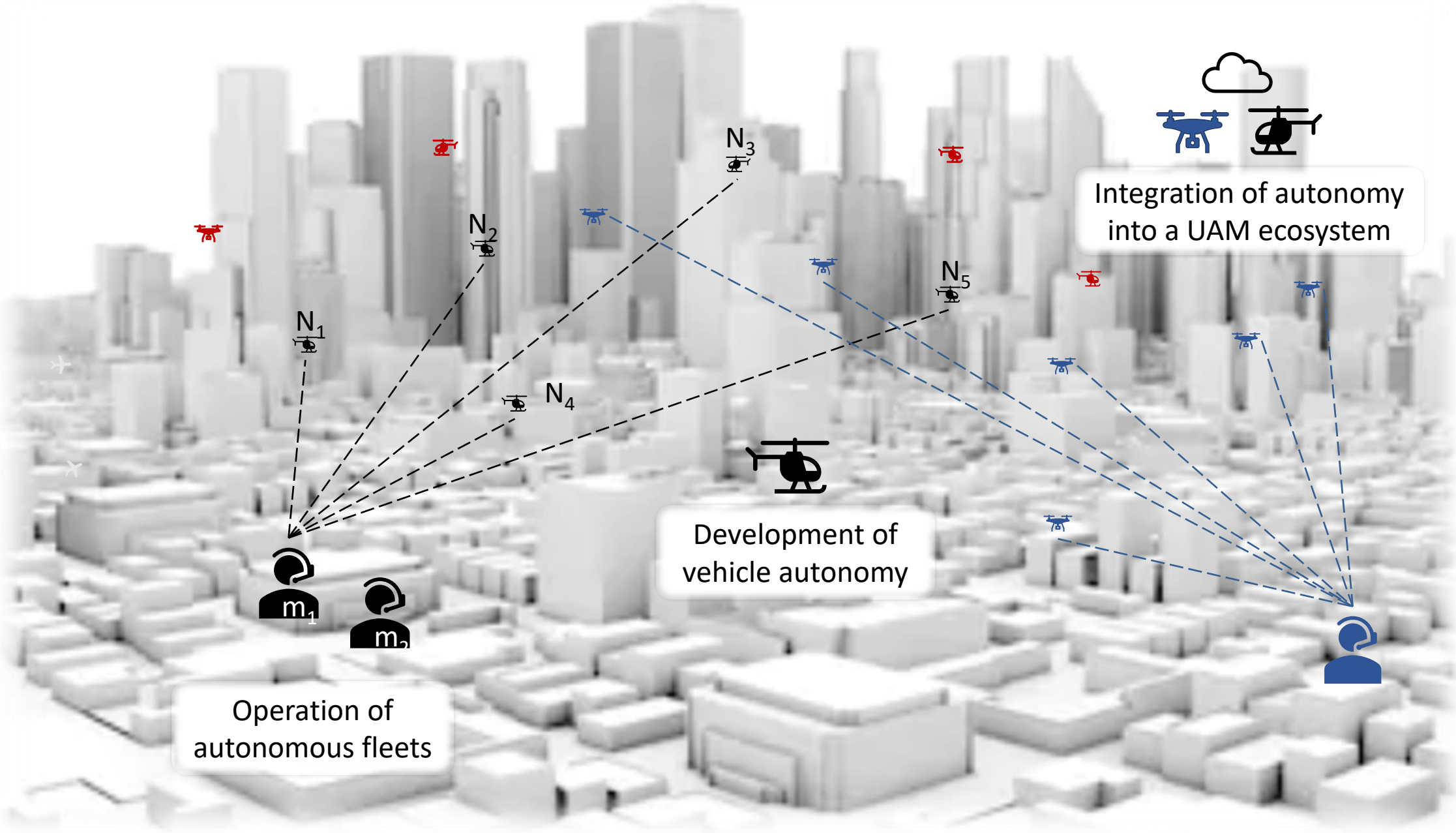
Advanced Air Mobility (AAM)
System-Wide Safety (SWS)
Air Traffic Management Exploration (ATM-X)
Revolutionary Vertical Lift Technology (RVLT)
Flight Demonstrations and Capabilities (FDC)
Transformational Tools and Technologies (T^3)
AAM Mission Integration Office (AMIO)

# Orientation: Revolutionary Aviation Mobility Sub-Project

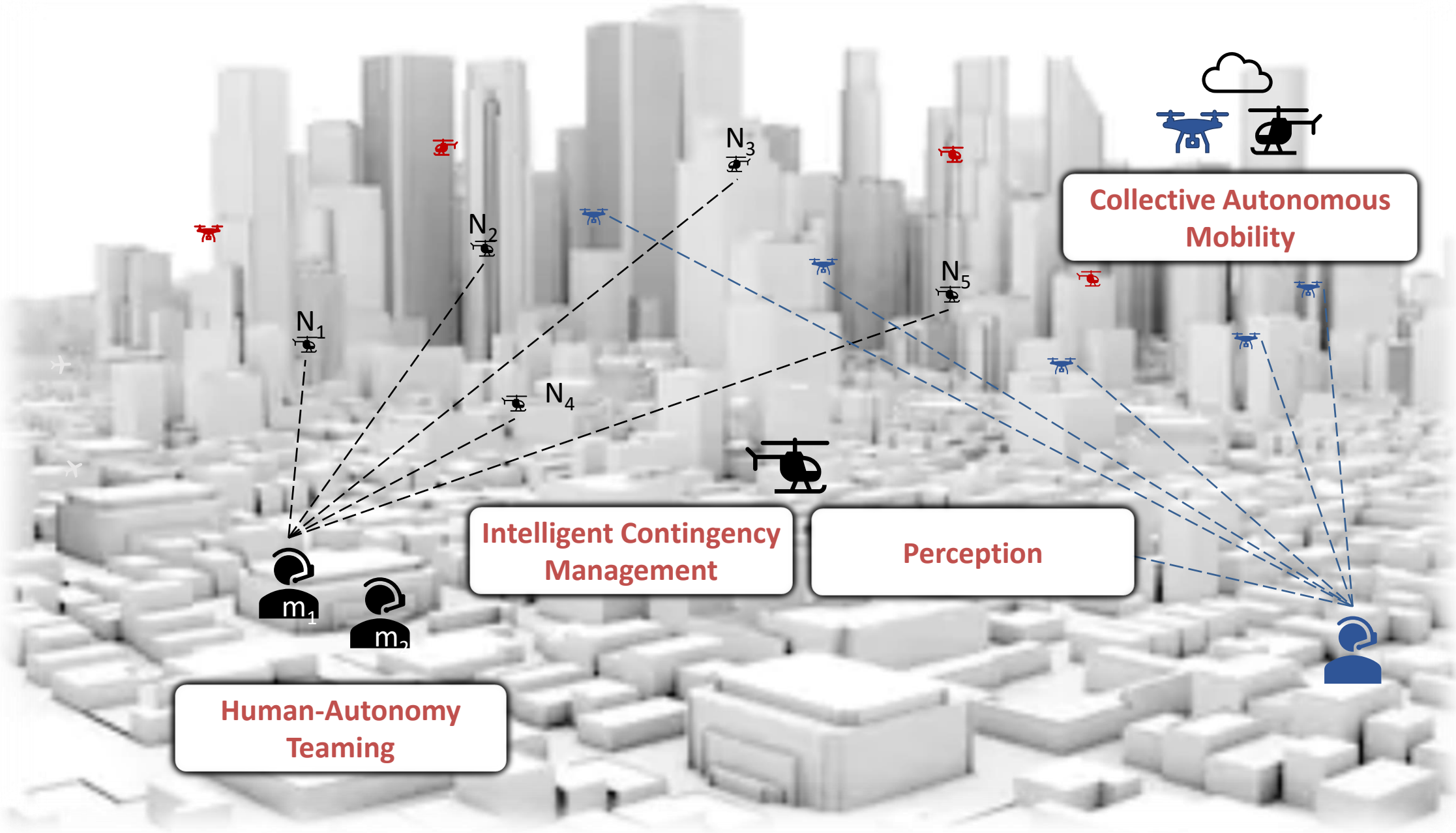
- Supports ARMD mission programs by providing a pipeline of solutions and knowledge for **foundational challenges in enabling an advanced air mobility market**
- Enables increasingly autonomous transportation in the **UML-4+ timeframe**
- **$10M/year investment** in autonomous systems technologies

| OBJECTIVES | |
|---|---|
|  | Enable scalable operations to achieve the full vision and potential of AAM through development of targeted tools and techniques critical for m:N operations of autonomous fleets [Draft TC] |
|  | Explore and develop airspace management and operations architectures and tools in expectation of increased heterogeneous air traffic |
|  | Develop modeling, performance, and control tools & techniques for advanced urban capable aircraft |
|  | Explore and demonstrate approaches for scaled vehicle production |

# Autonomous Systems discipline



# Autonomous Systems discipline



# Autonomous Systems discipline

## Human-Autonomy Teaming

- Distribution of roles & responsibilities
- Safe, effective teaming strategies
- Foundational research tools
- Human-in-the-loop simulation

## Intelligent Contingency Management

- Learning-based approaches to handle off-nominal conditions
- Autonomous decision tools to support range of UAM vehicle configurations
- Highly automated modeling techniques

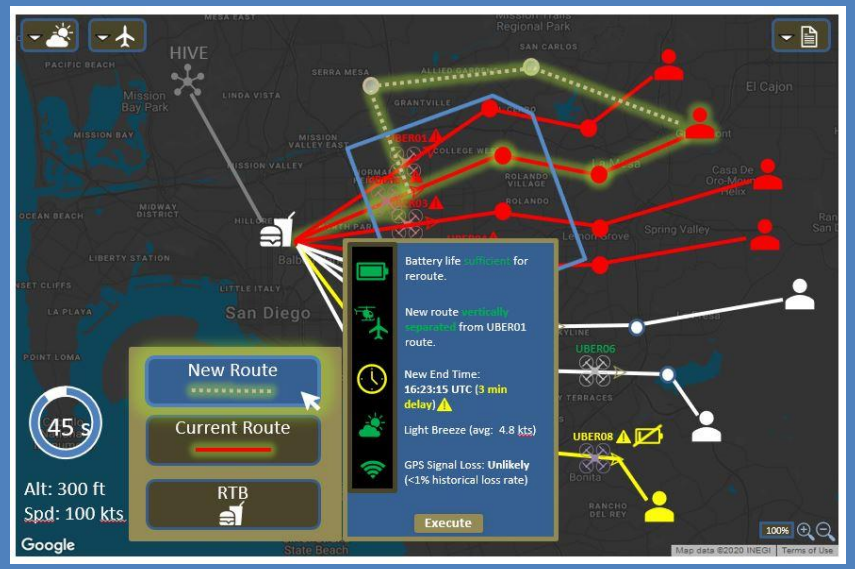
## Distributed Sensing for Perception

- Distributed sensing and collective reasoning techniques for self and situational awareness
- Research-enabling data collection
- CAS permeable boundary activity for weather tolerant ops

## Collective Autonomous Mobility

- Examine dynamic relationship among vehicles, operators, and service providers
- Coordination mechanisms for heterogeneous autonomous operations
- Quantum applications to airspace operations

# m:N Technical Challenge




## m:N Operations of Autonomous Fleets

**For efforts through FY27, $6M/year**

Enable scalable operations for AAM through development of an m:N operational approval roadmap supported by community coordination and critical tool and technique research

## Research areas

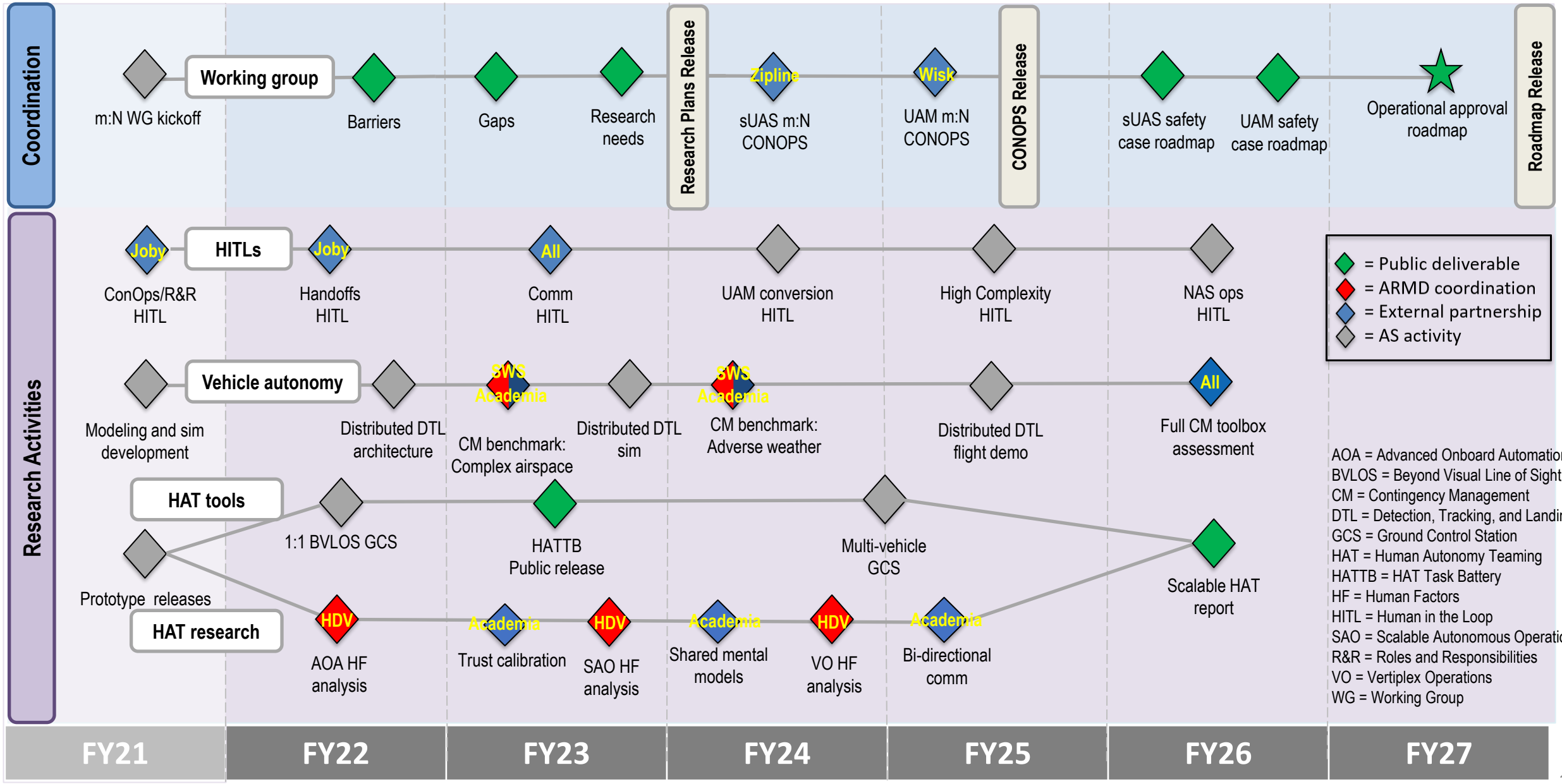
**Human-Autonomy Teaming:**
Develop tools and techniques to enable a small number of humans (m) to effectively manage many autonomous vehicles (N) across diverse use cases

**Autonomous vehicle technology:**
Develop **Sensing** and **Contingency Management** capabilities that enable vehicles to operate autonomously in UML 4+ scenarios with only high-level supervision from off-board humans

## Exit criteria

- Delivery of an m:N **operational approval roadmap** informed by coordination of stakeholder community and progress on identified technology gaps
- Release of **tools and data** from complementary research activities:
  - Publicly available HAT tools based on effective teaming study series
  - Publicly available data sets for perception tasks for multi-sensor and distributed algorithm development
  - Intelligent contingency management toolbox

# Work Plan


Coordination
Working group
m:N WG kickoff
Barriers
Gaps
Research needs
Research Plans Release
Zipline
sUAS m:N CONOPS
Wisk
UAM m:N CONOPS
CONOPS Release
sUAS safety case roadmap
UAM safety case roadmap
Operational approval roadmap
Roadmap Release
Research Activities
Joby
HITLs
Joby
ConOps/R&R HITL
Handoffs HITL
All
Comm HITL
UAM conversion HITL
High Complexity HITL
NAS ops HITL
= Public deliverable
= ARMD coordination
= External partnership
= AS activity
Vehicle autonomy
Modeling and sim development
Distributed DTL architecture
SWS
Academia
CM benchmark: Complex airspace
Distributed DTL sim
SWS
Academia
CM benchmark: Adverse weather
Distributed DTL flight demo
All
Full CM toolbox assessment
HAT tools
1:1 BVLOS GCS
HATTB Public release
Multi-vehicle GCS
Prototype releases
HAT research
HDV
AOA HF analysis
Academia
Trust calibration
HDV
SAO HF analysis
Academia
Shared mental models
HDV
VO HF analysis
Academia
Bi-directional comm
Scalable HAT report
AOA = Advanced Onboard Automation
BVLOS = Beyond Visual Line of Sight
CM = Contingency Management
DTL = Detection, Tracking, and Landing
GCS = Ground Control Station
HAT = Human Autonomy Teaming
HATTB = HAT Task Battery
HF = Human Factors
HITL = Human in the Loop
SAO = Scalable Autonomous Operations
R&R = Roles and Responsibilities
VO = Vertiplex Operations
WG = Working Group
FY21
FY22
FY23
FY24
FY25
FY26
FY27

# Partnerships

JOBY Aviation  wisk  zipline*

Multi-Vehicle (m:N) Working Group participants
-includes FAA, industry, and academia

Georgia Tech
Old Dominion University
University of Illinois at Urbana-Champaign
Sandia National Labs

Envision future connection to FAA Research Transition Team

Zipline Visit - December 2021

Will continue agile evaluation of future strategic partnerships to foster collaboration and forward progress

* SAA in progress

# m:N Working Group

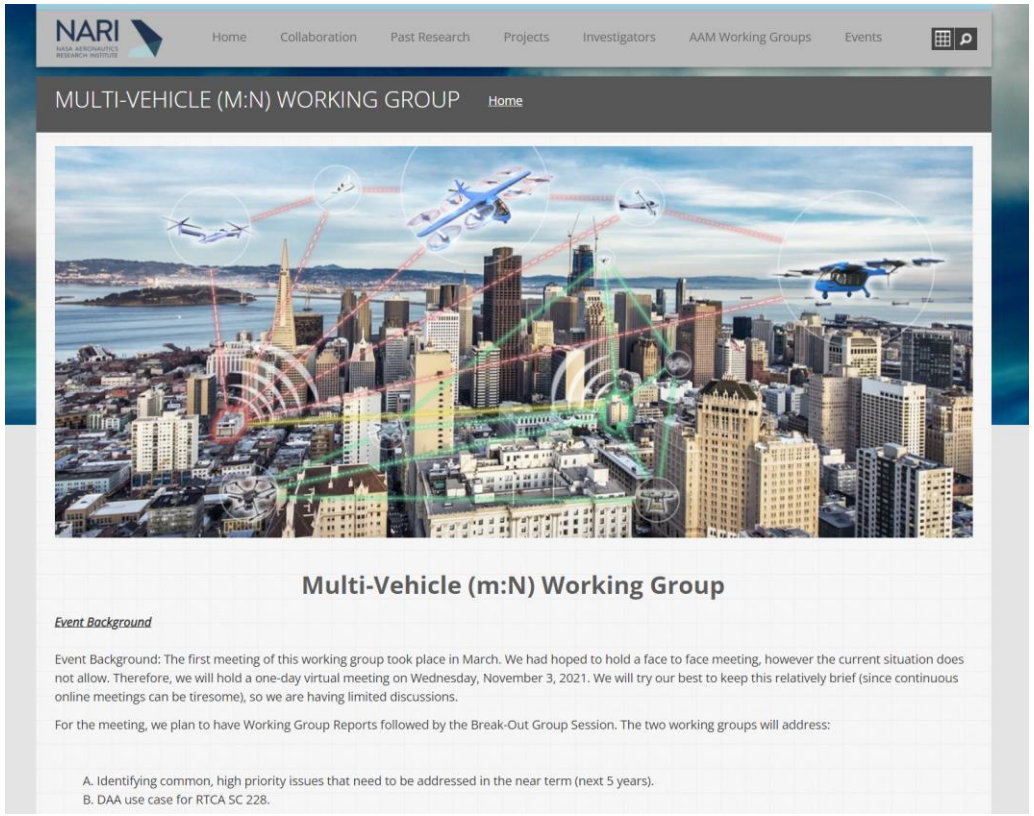
## NASA/TTT initiated m:N working group in FY21

## Participants

FAA

AeroVironment
Aurora
Boeing
Collins
General Atomics
GIUAS
HF Design Works
Wisk
IHMC
Joby Aviation
Loon
Northrop Grumman
NUAIR
SIFT
Zipline

Arizona State University
California State University Long Beach
University of Michigan




https://nari.arc.nasa.gov/multi-vehicle

# $T^3$ focuses on UML 4+